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NELSON ON "MATERIAL CULTURE"
GORTNER ON "BIOCHEMISTRY"

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SIGMA XI QUARTERLY

VOL. XX — SEPTEMBER, 1932 — No. 3

REPORTS OF RESEARCH DONE ON SIGMA XI GRANTS, 1931–1932

Professor F. E. Chidester, Professor of Zoölogy in West Virginia University, worked on the relation between nutrition and the endocrine glands. The most important advance was made in the study of antuitrin injections into the veins of chicks. A depletion of the thyroid iodin produced leg weakness. Iodin content of unheated milk and of cod-liver oil is significant in overcoming leg weakness, rickets, etc.

Professor Charles L. Fluke, Jr., of the University of Wisconsin, made a study of the taxonomic status of the adult Syrphus flies, since they constitute an important natural check upon the development of many injurious insects such as plant lice, leaf hoppers and certain scale insects. Practically all the types of these flies that exist in this country were examined as well as the species known to occur in Europe, with the result that four distinct genera are now recognized, two of which (Syrphus and Metasyrphus) have been revised and will be published in the Transactions of the Wisconsin Academy of Sciences, Arts and Letters, next spring; and the other two will be published in later issues of the Transactions. The first paper includes keys and descriptions of fifty-two species, and drawings of nearly all of them.

Miss Mildred Hebel, Teaching Fellow in the University of Tennessee, studied the order of plants known as the Papaverales, with special reference to the Mustard family.

Fossil evidence and comparative morphology support the theory of the polyphyletic origin of angiosperms. In the course of this evolution the Papaverales are descended from the Apetalae through the Hamamelidales and Ranales. This development is continued through the more plastic members of the order until the Parietales,

Cucurbitales and Carduales are evolved. Four of the six families of the Papaverales have representatives in the wild in Eastern Tennessee. The published account, a thesis "An Inquiry into the Phylogeny of the Papaverales together with a Taxonomic Study of the Order in Eastern Tennessee," contains a list of 76 species in 32 genera, and analytical keys and critical diagnoses for these species and genera.

Professor Rachel Emilie Hoffstadt, Assistant Professor of Bacteriology in the University of Washington, continued a study on the mechanism of infection and local immunity. One part of the study dealt with the dissociation of the organism, Staphylococcus aureus. Treatment with heat kills cultures of the whole or the dissociated form, but dissociation does not affect the virulence of the organism. Dissociated forms are not pathogenic. The physiological characteristics of the dissociates differ from the parent organism.

A second study on the same organism resulted in the conclusion that bacteriophage is not an essential factor in microbic dissociation but may be produced simultaneously with it.

A third study concerned the relation of disinfectants to the killing of variants of the organism. The lethal coefficient of six common disinfectants was run against moist and dried forms. All forms varied with the disinfectant used.

Professor Claude R. Kellogg, Professor of Biology, Fukien Christian University, Foochow, China, made studies on the Chinese honey bee. The work is being done at the Massachusetts State College in Amherst. Great difficulty has been experienced in getting the Chinese bees into this country in a condition in which they can be studied. Ways of eliminating the difficulties have been found, and some bees have been shipped successfully across the waters. Necessary equipment has been purchased on the Sigma Xi grant, which it is proposed to use in the study of the genetics of the honey bee found here as well as those to be brought from China. One paper has been prepared and submitted for publication and a second is about completed.

Mr. Thomas Large, Instructor in Zoölogy in the Lewis and Clark High School, Spokane, Washington, studied fish fauna and their food and habits, with particular attention to the spawning of anadromous fishes. The spawning of the Chinook salmon was the main object of the research, which was undertaken in the Wallowa Mountains of Oregon. Time was given to a study of the region geographically and physiographically, the period of arrival in the spawning migra-

tions and the changes of stream conditions as they affect the fish. The question of the alleged destruction of the eggs by bull trout, one of the serious enemies of the Chinook salmon, received considerable attention. Observations seem to indicate that the fish reported as bull trout are small Chinook males, and the acts described as rushing under the spawning female to eat the eggs are in reality the attempt of the males to deposit their sperm over the eggs, while the larger males seemingly strive to prevent this. A land locked silver salmon was found, which afforded opportunity for future study of the instinct to return to the sea. Mr. Large read two papers before the Spokane meeting of the Northwest Scientific Association covering some of his work on this grant.

Professor Ann Haven Morgan, Professor of Zoölogy, Mount Holyoke College, made a special study of winter conditions of certain animals, and two papers involving results of the work have been published, namely, "Winter Habits and Yearly Food Consumption of Adult Spotted Newts, Triturus Viridescens," and "The Function of Gills in Burrowing May Flies, Hexagenia recurvata."

Adult spotted newts have been found to be semi-active in the water throughout the winter, often temporarily clustered in groups of 20–40. They ate frequently all winter and were found with recently eaten food in their stomachs when the air temperature was at zero F. They also shed their skins throughout the winter.

The function of the gills in the May fly Hexagenia was also studied with particular reference to the winter season. Nymphs that lived without gills through the winter period of lowered activity were unable to survive through the spring. The oxygen intake of normal nymphs was approximately twice as much as that of the gill-less ones. Normal nymphs eliminated CO_2 more than twice as fast as gill-less ones. In gill-less nymphs, exchange of gases appeared to occur through the body wall. Normal nymphs are generally photo-negative except before emergence. After gill removal they became photo-positive, the condition appearing to correlate with their contents of CO_2. Nymphs that lived through the winter without gills were inactive, made few spontaneous movements and rested upon the surface of the mud, whereas their controls were active and burrowed freely. From November to March control nymphs molted rarely; gill-less ones, not at all. No regeneration of the gills was observed on the experimental animals, though a few specimens with regenerating gills were found in collected material.

Professor Alexander Petrunkevitch, Professor of Zoölogy, Yale University, studied the structure, development and activities of Hypochilus thorelli, the only spider of the sub-order Arachnomorpæ possessing four lungs and found in Tennessee and Georgia. The main geographical area inhabited by Hypochilus has been ascertained to be a triangle with its apex at Blowing Rock, N. C., and its base extending from Maryville, Tenn., to Tallulah Falls, Ga. The area includes the Great Smokies, the Nanthala Mountains and the southern half of the Blue Ridge. Lookout Mountain and the Walden Ridge lie considerably to the west of this area and represent probably the westernmost extension in the distribution of Hypochilus. A gap of some width lies between this and the eastern area, so far without any indication as to the manner or path by which the invasion of this narrow strip has been accomplished.

The study is being continued in New Haven on specimens collected while the geographical area was being defined. Many specimens were preserved in fixing fluid for microscopic study, others in alcohol for the museum and seventy living specimens were put into individual aluminum containers for transportation. Sectioning and studying the anatomy has been done, drawings made and a manuscript is being prepared for future publication.

Mr. Richard Stephen Uhrbrock, Head of the Statistical and Research Department, Industrial Relations Division, Proctor and Gamble Co., Cincinnati, worked on racial and sex differences in finger print patterns. Studies were made on 1248 finger print records. Colored males show a slightly greater percentage of whorls than white males, but white males have more loops and arches than colored males. The three differences were not greater than one standard deviation of the difference; hence all differences can be accounted for by chance alone.

Male whites have a greater percentage of whorls than female whites, the differences being over six times its standard deviation. Female whites have a greater percentage of loops than the male whites, the difference being over four times its standard deviation. The females also have more arches than the male whites, the difference being over three times its standard deviation.

While, therefore, no statistically reliable difference can be discovered in the percentage of patterns of the white males and the negro males, the differences between the white males and the white females are statistically significant.

Thorndike Intelligence Tests scores were available for 159 male whites and 107 female whites, and advantage was taken of this situation to study the possibility of the existence of a relationship between finger print characteristics and general intelligence. All ridges were counted on loop and whorl patterns. Correlations between number of ridges in loops on the ten fingers, and intelligence as measured by the Thorndike Test, were found to be low but positive. By substituting the ridge counts of loops on the ten fingers into the proper equation, it was found possible to predict the intelligence test scores fairly well. The correlation between the predicted scores and the actual scores is +.453.

Professor Paul Weatherwax, Associate Professor of Botany, Indiana University, took for his project a study of the phylogeny of the grass family, especially that of the Indian corn plant. Two months were spent in Guatemala and a short trip was made inland at Tela, Honduras. Complete collections were made of the grasses available, from the jungles along the east coast up to an altitude of 7000 feet. Trips were made to the Pacific coast and almost to the frontier of El Salvador for special forms. A general collection of grasses was secured in the form of about 400 numbers, consisting of herbarium specimens, seeds and alcoholic material for anatomical work. Special collections were made of certain genera of critical importance in agrostology. A search about Maya ruins, both in the jungle and in the highlands, for evidence as to the origin of the corn plant led to the conclusion that the solution of the problem is to be looked for elsewhere. It became evident that teosinte, a near relative of the corn plant, has a wider distribution than it has been thought to have.

Professor Charles Ernest Braun, Assistant Professor of Organic Chemistry, University of Vermont, worked on the relationship between structure and hypoglycemic activity in some substituted guanidines. A number of simple guanidines, either isomeric or closely related structurally, were synthesized and their physiological effects on normal rabbits were observed. Most of the compounds made are aromatic guanidines, selected to test the theory that "the aromatic nucleus is not productive of hypoglycemia." In the preparation of the eight guanidine derivatives studied special effort was directed toward a high degree of purity rather than to quantity of yield. Physiological activity was determined by the usual blood sugar technique. Normal rabbits starved for 24 hours prior to ex-

perimentation served as the experimental animals. The guanidine derivative was made up in isotonic salt solution and administered by subcutaneous injection. Blood sugar was determined on blood samples taken at regular intervals following injection. Physiological results obtained to date on benzyl-guanidine sulfate show that this compound in doses of 35, 40, 50 and 75 mg. (calculated as free base) per kilo of body weight exerts a marked hypoglycemic action preceded apparently by a hyperglycemic effect. Hypoglycemic convulsion is relieved immediately by injection of glucose. These data though incomplete indicate that this compound produces a marked lowering of the blood sugar in a normal rabbit within four hours without causing noticeable toxic symptoms or death. Since practically all of the aromatic guanidines investigated by other workers were very toxic and in most cases killed the animals whenever hypoglycemia was produced, the apparent relatively low toxicity of benzyl-guanidine places it in a rather unique position among the aromatic guanidines studied to date.

REPORT OF COMMITTEE ON SIGMA XI GRANTS-IN-AID FOR 1932–1933

The Committee on grants-in-aid of research met in the Faculty Club of Harvard University, Friday, July 1, at 2:30 P.M. Present were Professor Harlow Shapley and Professor Gary N. Calkins of the committee, and Secretary Ellery as executive officer of the Society. Thirty-three applications were received and considered.

The following actions were taken:

Charles Ernest Braun, Assistant Professor of Organic Chemistry, University of Vermont, Burlington, Vt. Continuation of the study of the relationship between chemical constitution and hypoglycemic activity in guanidines, $175.00.

Norman Ethan Allen Hinds, Associate Professor of Geology, University of California at Berkeley. Continuation of analytical work for report on petrography of Kauai and Niihau, Hawaii, $150.00.

Rachel Emilie Hoffstadt, Assistant Professor of Bacteriology, University of Washington, Seattle, Washington. Continuation of study on mechanism of infection and local immunity, $250.00.

Carney Landis, New York Psychiatric Inst., Research Associate. Investigation of the electrical changes of the skin, $225.00.

Walter F. Loehwing, Professor of Botany, State University of Iowa, Iowa City, Ia. A study to determine the effects of certain essential inorganic nutrients in the vegetative and reproductive cycles in plants, $200.00.

Ruth Marshall, Professor of Zoölogy, Rockford College. Completion of a preliminary list of Wisconsin Hydracarina, $100.00.

Seward E. Owen, Assistant Professor of Physiology and Pharmacology, University of Utah Medical School. Physiology of the Myoneural Junction; Jaundice and Diuresis; Nephritis and Hypertension, $300.00.

Charles Vincent Taylor, Professor of Biology, and J. Murray Luck, Professor of Chemistry, Stanford University. Effects of very intense soft x-rays on protozoa, under accurately reproducible conditions, $500.00.

Total $1900.00.

(Signed) GARY N. CALKINS
HARLOW SHAPLEY

THE ORIGIN AND DEVELOPMENT OF MATERIAL CULTURE *

N. C. NELSON, CURATOR OF PREHISTORIC ARCHAEOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK

At this time, when the evils of industrialism and militarism are being so widely discussed, it seems peculiarly appropriate to inquire into the origin and early development of the mechanical inventions upon which these two civilizing agencies are founded. The inventions concerned, namely, tools and weapons, have a very long history. That is, regarded either as instruments or as symbols of power, respectively over nature and over man, tools and weapons have occupied a prominent place in human endeavor for hundreds of thousands of years; but it is only lately that mechanization has been well-nigh perfected and that as a result we are all being made unavoidably aware of the abuses of which they are capable. Stated more specifically in the language of the day, because we are in the midst of a world-wide economic crisis, blamed partly on speeded-up machine production, and because also of recent wars and threatening future wars due, some say, to the excessive development of armaments, interest in the history of mechanical appliances is no longer confined to merely academic circles. Tools and weapons are now topics of both public and private concern. It is being realized that when our early ancestors took to improving sticks and stones for use as implements, they started something which had and continues to have inescapably serious consequences. Tools and weapons, as the instrumentalities by which alone the world's present population maintains its existence and the nations their sovereign powers, are readily seen to be of the utmost practical importance, as well as of peculiar scientific interest. It is not strange, therefore, that in some form or other our topics, tools and weapons, are today being discussed as no other topics were ever before discussed in all the world's history.

The inquiry into the early history of tools and weapons, strange to say, is of recent date. Vague speculations about primordial origins there have been for at least some thousands of years on the

* Lecture delivered before the Pittsburgh Chapter, Society of the Sigma Xi, March 16, 1932, being one of a series of public lectures on "The Culture of Prehistoric Man."

part of unfettered minds like those of classical Greece; but systematic investigation is little more than a century old. Up to less than two hundred years ago our most learned European forefathers uniformly regarded stone implements literally as thunderbolts, *i. e.*, curious shapes formed in the atmosphere when the lightning flashed. There were reasons, of course, for such fantastic explanations, still held by many even civilized peoples; but while we smile, it is well to remember that if America had never been discovered and stone implements not observed in daily use, the chances are we should all be regarding such objects as inexplicable mysteries still. As it is we owe our rational views not to prejudiced book students but to men of common sense who dared believe what they saw with their eyes. This story of our partial conversion to reasonableness has not yet been adequately written, but it is one of the most illuminating in the whole history of science.

Now this being a Sigma Xi occasion and your speaker's professional interests being supposedly limited to the prehistoric past of man's cultural development, he has assumed that he is expected to deal only with the early and elementary forms of tools and weapons. And doubtless an hour's time could be profitably devoted to a descriptive account of the primary forms, functions and genetic relationships of the implements in question. Such an account would as a matter of fact cover all but a very small portion of the timespan involved in human culture history; *i. e.*, it would embrace a million years or more as against the five thousand years or so of time covered by written historical records. Yet so important for a true appreciation of the unknown initial steps in the invention of implements is a recognition of the known happenings leading up to the present status of our mechanical developments that I find myself unable wholly to ignore them. I venture, therefore, to depart somewhat from the limited implications of my specified subject and to direct your attention briefly to the whole theme of man's material achievement or, as anthropologists are wont to phrase it, his material culture. In other words, I propose to consider implements or mechanical inventions, *i. e.*, material culture phenomena, as parts of a unique unfolding *process* which has much in common with that other process observed in the world of nature and generally called organic evolution. This shift in viewpoint, together with the limited time at our disposal, makes extended analysis and classification of tools and weapons as such impractical. For present purposes, therefore, all the works of

man's hands, whatever their nature, are regarded indifferently as inventions, as implements and as elements of material culture, the three words—invention, implement and culture—being used as more or less synonymous. The aim is, however, to confine the discussion to objective and quantitative facts and to use only primitive implements for purposes of illustration. Exhaustive treatment of so vast a subject is also out of the question. The best that can be done is to touch only the high spots or the outstanding aspects of the subject and I propose therefore to group my remarks under the following seven headings: The familiarity of implements, the increasing number and variety of implements, the nature of implements, the origin of implements, the development or specialization of implements, the limitations of mechanization and the social consequences of mechanization.

General Familiarity of Implements

Fortunately the subject of mechanical appliances is one with which we are all familiar. Scarcely a day passes that we do not employ artificial contrivances of some sort; but intent as we must be on immediate tasks, we seldom stop to wonder about the actual history of the implement used. Indeed, implements being as common as they are, most of us doubtless take them for granted even while we know very well that at least some of them, like the radio, came into existence only yesterday. There may be those among us who never have imagined life without knives and forks, napkins and toothpicks, needles and scissors, pens and typewriter, telephones and automobiles—to name only a few items in almost universal use among civilized peoples. Yet time was, not so long ago, when our ancestors managed without all but two of these inventions; and if it is true, as astronomers claim, that planets take shape only to dissolve again, then obviously the time will come when implements must once more disappear, the last inventions being presumably the first to go. Even now, during our period of rapid progress in mechanization, old inventions are continually being discarded for one reason or another: the toothpick is frowned upon in polite circles; the pen, fortunately, is little used by many of us except for proving our identity by a more or less unique and illegible flourish; and the horse-drawn carriage of Washington's day has been largely superseded by no less than four successively swifter means of transportation—the steam train, the bicycle, the automobile and the airplane—the last three of them

having appeared within the memory of some of us here present. These are but random selections from hundreds of recent important changes and improvements in our mechanical equipment, due to the fact that inventing or designing, which was formerly left to chance individual initiative, often resisted by popular enertia, has finally become one of the recognized and even one of the organized professions, with the result that new patents are now granted liberally every day.

The Increasing Number and Variety of Implements

The suggested speeding-up of the stream of mechanical inventions during historic times is a significant fact precisely in keeping with the apparently few and far between contrivances developed during prehistoric days. To demonstrate this acceleration of the inventive process it is only necessary to examine, as it were, a few cross-sections of the flow taken at strategic points.

First, let us go back to the earliest positively ascertained cultural beginnings as revealed by recent researches, especially in England and China. The more conservative archaeologists practically agree in placing the date near the close of Tertiary times, or, in other words, near the commencement of the so-called Ice Age, about one million years ago as geological time is now reckoned. At that stage man's whole existence, so far as the external world was concerned, appears to have centered about the quest for food. There are no indications of either clothing or shelter construction. Man was simply a roaming hunter, following the animals on which he subsisted in their seasonal migrations. His outfit of stone implements was small and was probably made to order as occasion demanded, but is regarded nevertheless as exhibiting the germ idea of at least five primary tools, namely, the hammer, the chopper, the knife, the scraper and the perforator. He probably also possessed weapons of wood, such as the spear and the club, but of these traits actual proof is lacking. We have therefore at this time, close to the commencement of distinctly human activities, a demonstrated stone industry, together with an implied wood industry, and the period has accordingly been called the Lower Paleolithic or Early Old Stone Age.

In passing, it must be stated here that there are, and have long been, a number of ardent prehistorians who believe that they see evidence of man as a tool-user, if not a tool-maker, well on toward the beginning of the Tertiary era, or back about thirty-five or forty

millions of years. The alleged proofs are found mostly in western Europe and consist of numerous angular flints with edges more or less chipped, it is believed, as the result of use by man. These supposed semi-artifacts are called *eoliths*, or dawn stones, and are regarded as exhibiting the rude generic forms of at least three, or perhaps four, of the five primary tools already mentioned, the sharp-edged forms having served possibly the purposes of both knife and scraper, if not also that of chopper. It is generally recognized, of course, that at the earliest imaginable beginnings human wants were limited to such instinctive cravings as hunger, love and play, the first two of which, the poets tell us, still rule the world; and that under such conditions few implements could have been needed and that these, in the first instance, would have been natural sticks and stones of a character so crude as to be unrecognizable by us, even if preserved. Nevertheless, the subject of Tertiary eoliths is still problematic after sixty-five years of dispute and it is mentioned here only as a fascinating digression.

The next strategic point at which to examine the swelling contents of our culture stream is near the end of the Ice Age, or about 15,000 years ago. At this time the hunting mode of existence appears to have reached its highest possible development (barring that of the present-day Eskimo), and we find many new and interesting improvements, which compel us at least to recognize our kinship with the originators. To the ancient hunting activities have now been added the use of fire, the use of skin clothing and the occasional use of some sort of artificial shelter. Esthetic crafts like sculpture, painting and the making of body ornaments are practiced, and there are indications also of ceremonial performances, including magic rites, religious dances and formal burial of the dead. Nearly all of these activities are demonstrated to us by objective evidence. In the way of actual implements we find all told about thirty readily distinguishable forms, besides half a dozen or so of ornaments. About half the total number of these inventions are of stone, largely chipped stone; while most of the other half are of bone and antler, with only a few derived from wood and shell. As to general functions, these articles comprise about eighteen tools, two utensils (the mortar and the lamp), twelve weapons and about six varieties of ornamental objects. The most complicated inventions of the day were two combination weapons, namely, the spear with a special apparatus for hurling it and the bow with its necessary arrows. Probably weirs

and traps were also devised for catching fish and game but of these no remains are yet available. In brief, we have reached a point in the culture process where we see the emergence of several of our own major activities. Industries in stone, shell, bone and hide are under way. The period in question is called the Upper Paleolithic or Late Old Stone Age, but could more appropriately be called the Bone Age, owing to the relative abundance and perfection of its bone implements.

Coming down now to a point in time, say about 7000 years ago, we find, especially in the general region where Europe, Asia and Africa meet and where therefore ideas of different sources mingled, that strange and revolutionary changes have taken place. The roaming hunter's life has largely ceased and man has become rooted, as it were, in the soil. Permanent group settlements of artificial habitations appear, and for their mainstay the inhabitants have resorted to the cultivation of domesticated plants and animals. This sedentary mode of life has given opportunity for division of labor, specialization and consequent rapid progress in invention. Various textile and ceramic arts suddenly make their appearance, the new method of shaping stone implements by pecking and polishing is discovered, and crude hammering experiments are being made with such new malleable raw materials as copper, gold and meteoric iron. Before long true metallurgy is born and at about the same time writing is invented, presumably in answer to the demands of commerce and the conduct of organized community life. All of these newborn activities required new and specialized implements—so many in fact that it is no longer practical to count them; but an inventory would reveal probably not less than three hundred artificial contrivances. Most important among the ordinary stone tools is the first appearance of the pick, the axe, the adze, the gouge, the chisel, the grindstone and the whetstone. In short, we have arrived at the real beginnings of what civilized man is enjoying today, namely, the nearly complete artificialization of existence. Because this beginning was based on a new class of stone implements made by hammering or pecking and finished by polishing, the period is called the Neolithic or New Stone Age, sometimes the Polished Stone Age.

As the final step in our survey of mechanical expansion, let us consider briefly our own present status. To count the number of implements in use today is out of the question, but we may at least gain some idea of the variety of purposes for which they are used. Early

in the 17th century the great Sir Francis Bacon made several attempts to classify human knowledge, and so made lists of all the topics of special interest about which, for example, histories could be written. One such list enumerates in all one hundred and thirty topics, in which are included all the sciences, arts and industries, as well as the other activities then known. Such a list would today be many times longer, as may be found by actual comparison. Thus, the "gainful occupations" cited in the U. S. Census Report for 1920 number almost exactly seven hundred, and it is far from a complete analysis. "College Professors," for example, in spite of their widely differing ranges of interest, are grouped with "College Presidents." Also there are many human activities besides "gainful occupations" which use implements of one sort or another, the principal one not so recognized being that of housewife. The manufacturing arts and industries alone, according to the latest (1925) report of the Department of Commerce, run into several thousand, although for census purposes only three hundred and seventy are actually named; and every one of these presumably employs more or less specialized tools. The only conclusion to be drawn is that the world's present inventory of implements of all types runs into several thousand.

If we ask the reason why of all this progress, the same census report states that in 1920 nearly 2500 of our American citizens put themselves down as "inventors," while over 15,000 claimed the rank of "designers." The number is astonishingly small, considering the size of our population, and very likely it is incomplete; but the services of these few inventors are today greatly augmented by the existence of transportation facilities which convey all generally useful productions to the ends of the earth in a few weeks after they are placed on the market. Then, too, inventing has of late become a recognized profession. Thus, Thomas Edison, according to recent press reports, was granted during his lifetime no less than 1180 patents. And speaking of patents, Professor Mark Jefferson a few years ago published an interesting article on the subject, in which he states that up to 1870 there were in the world less than 400,000 patents registered, while now there are over five millions. He adds further that the patents registered for 1925 in thirty-two countries amounted to 180,000. It is true not all of these patents refer to actual tools or even implements in the stricter sense of the term, but they do refer to some item or other among the mass of concrete paraphernalia which civilized man employs, and in so doing more

and more isolates himself from direct contact with the raw natural world.

What, it may be asked, will be the outcome of this tremendous activity? And if it continues as heretofore, how are we going to keep abreast of the times? Those are legitimate questions, not to be answered here, however, because the present purpose is merely to call attention to the geometric rate of progression exhibited by the inventive process in the purely mechanical realm of human activities.

What Are Implements?

Having taken a bird's-eye view of our mechanical culture stream, it is next in order that we scrutinize its contents. As we have observed the great variety of man-made things pass before us the question must often have occurred: Just what is an implement? Many definitions are possible but none is entirely satisfactory. We have seen what implements are made of and we know in a general way all about their forms and functions; but, in the scheme of things which we call every-day existence, what is the essential nature of implements? A possible commonsense answer might be that implements are devices, contrivances—in short, inventions—by means of which we do work or accomplish purposes which we could not achieve barehanded. Some have carried this general idea so far as to say that implements are in a sense outgrowths or extensions of the hands. Webster, in fact, tells us that the word implement came from the Latin *implere, i. e.*, to fill up, to finish or to complete.

But such statements and definitions get us nowhere. The question still remains: What is an invention? We have no time to deliberate on the reply, but every one will presumably agree that an invention is something that has been thought out, and by means of the hands tried out, until it was adapted to do the particular work for which it was intended. This may be an awkward and unilluminating definition; but it is about the best that can be offered on the spur of the moment. Enlarging upon it, we may say that mechanical inventions, like words in the linguistic realm or like institutions in the social realm, are ideas that have been objectified or realized in form or substance appreciable to the senses; and that in this concrete shape our ideas—entities of the mental realm—become serviceable for doing otherwise impossible things in the physical realm. Perhaps we are not getting anywhere with this explanation, but it amounts to this: that in contrast with the lower animals man lives less and less by

mere brute strength and literally more and more by his wits. We are not in position, however, to look down on the animals and to pride ourselves on having accomplished something absolutely unique, for, on the one hand, force still governs to some extent in the human world and, on the other hand, the animals dig burrows, build nests or dams, and even on occasion use ready-made objects after the manner of tools. It is said of course that animals do these things instinctively; but after all most of us still accept the good things of life as we find them, making few if any consciously aggressive efforts to help along the cause of civilization. In short, we are not equally endowed with the capacity for inventing, but even if we were, as members of organized communities, we should of necessity have to live partly at least by the wits of others; for that, essentially, is what cooperative life means—the giving up of being jack-at-all-trades in order to become master of one. The change has obvious advantages but it also has disadvantages.

Origin of Implements

The next question to confront us is: How did implements originate? The present answer is: Nobody knows; that is, we have no strictly scientific evidence on the subject and probably never shall have. Perhaps the psychologists, who are studying the behavior of children and who are also experimenting with captive animals—especially some of the apes—may ultimately furnish us with valuable indirect clues. At present we know only that the farther we go back in time the fewer the available implements become and the cruder also is their form. With that archaeologically demonstrated trend in mind, we may allow ourselves to speculate a little on the probable conditions that led to the momentous step which resulted in what we now call mechanical inventions, the essential basis of modern civilization.

First of all, a word as to our absolute need for implements. Man, as we see him today—except for his large brain and dexterous hands—is a relatively weak and unspecialized member of the vertebrate group to which, zoölogically speaking, he belongs. The mammals, many of them, can outrun him; the fishes can outswim him; and he cannot fly at all; he is provided with neither powerful teeth nor claws; and his ordinary senses are apparently less keen than those of his fellow creatures. In other words, man is outmatched as regards mere brute strength, and in the struggle for existence, consequently,

has survived only by the use of his wits. Demonstrably, our proto-human ancestors during Tertiary times were somewhat better equipped physically; but the chances are that they were always and increasingly at the mercy of their more highly specialized fellow mammals and that they were ultimately caught in some exceptionally tight situation from which they could extricate themselves only by artificial means. Precisely how it happened is impossible to say; but, doubtless, it was the first illustration of the old adage that necessity is the mother of invention, and doubtless, too, it did not take place all in an instant—any more than is the case with our great modern inventions—but was the result of at least three or four distinguishable steps or stages ranging, we must suppose, over a tremendously long period of time.

The first step, *i. e.*, the use of implements, or the adoption of extraneous physical means for accomplishing necessary or desirable ends, may have been prompted either by the play instinct or by the instinct for self-preservation, more likely the latter. Our barefisted ancestors conceivably in sheer desperation picked up sticks and stones either for purposes of defense or offense, or for the purpose of obtaining food out of direct reach, much as the caged chimpanzee will do today.

The second step follows naturally. Not every stick or stone was manageable or useful. Nature at the outset compelled a choice and the purpose in view made further discrimination necessary. Even such simple operations as the reaching for a fruit-bearing branch or the clubbing or stabbing of an animal could not be done equally well with the same implement: a sharp-pointed stick was best for stabbing, a thick and stout one for clubbing and a hooked one for pulling down branches. In other words, ideas, or a rude form of thinking in the shape of purposeful selection of means suitable to the ends sought, are implied almost at the start, and once that selection of well-adapted natural objects had been achieved or had become habitual the first differentiated tools and weapons were born. This exceedingly simple trial-and-error method of getting sticks and stones of a certain size and shape associated with success in obtaining food or warding off enemies presumably occupied many millions of years and is represented, according to some, by the so-called Eolithic stage. But whether or not the particular chipped stones already described were actually used by our human precursors matters little; some such stage during which nature-made objects served as rude

implements is inescapable. In proof of its reality it may be pointed out that the common hammerstone—the father of nearly all the other stone implements—is to this day for the most part nothing but a selected natural bowlder. Fire also was doubtless for thousands of years an agency borrowed from nature until eventually, by some accident or other, man learned to produce it artificially.

The third step, the one that finally separates man from the other animals or, in other words, distinguishes man as man, is perhaps the most difficult to visualize. Yet in view of what has just been said about the preparatory stages we cannot be greatly surprised by the next and most important event in all culture history. The faculty of choice or discrimination, exercised in the adaptation of nature-made implements to such constantly desirable ends as food-getting, developed in the course of time to the point where it was recognized that almost any stone of manageable size was suitable for crushing or shattering, that sharp-edged ones were especially adapted for chopping, cutting and scraping, as were sharp-pointed ones for stabbing, digging or perforating. As the result of long usage for some of the purposes indicated, certain of these nature-made implements, such as those serving as knife or as perforator, were bound to become chipped and dulled, somewhat after the manner of eoliths, and consequently had to be discarded. If now new and sharp natural substitutes were not ready to hand they could easily be obtained in one of two ways: either by striking or hurling a flint nodule against another rock or by striking the flint nodule with a small bowlder held in the hand. The shattering effect of such procedures had been observed many, many times as the result both of accident and of play; and the second method, that of shattering the flint nodule with another rock used as a hammer, came to be preferred doubtless because, in the first place it, was the less dangerous so far as erratically flying splinters were concerned and, in the second place, because it also yielded the best results in the way of flakes, owing to the fact that the blows delivered with a hammerstone were controllable or could be directed at will The earliest positively recognizable man-made implements that have come down to us are therefore nothing but rough and irregular flakes and the equally rough cores from which the flakes were struck. At first apparently only the flakes were used, used just as they were for cutting, scraping, etc.; but in time the cores came to receive special attention and were by a few swift strokes actually shaped into large and clumsily pointed

blades suggestive of monster spearpoints or knives. That is, we obtain here for the first time a purposely designed implement, called by various names, such as coup-de-poing, faustkeil, cleaver, hand-ax, etc.—an implement which for a long time has been believed by many archaeologists to have been a sort of universal tool, suitable for several different purposes, and in fact the first true implement that man ever made.

The fourth and last step which we need consider has to do with a new method in fashioning flint implements. Hitherto, as we have seen, all flake and core tools have been produced by a swift and only partially controllable stiking process. The next advance introduced was the shaping and sometimes the resharpening of the edge of flint-flake tools by a much slower but more easily controlled procedure, consisting in the removal of small marginal chips by means of pressure, exerted with a pointed stone or bone at the particular place where reduction was desired. This last step was achieved long before the end of the Ice Age by the so-called Neandertal man and continued in exclusive use down to less than 10,000 years ago, when man learned to work stone, after the manner of the modern stonecutter, by pecking, grinding and polishing.

We now have implement making well under way and need not follow the art any farther, for by this time inventing had become at least a partially conscious effort for some individuals and proceeded much as it does today—except that there were then no actual patent laws. The clever man of prehistoric days was not, however, without his reward: a study of primitive legends everywhere reveals the culture hero, *i. e.*, the man who had added some special contribution to the equipment of his people and thus made easier their struggle for existence. Among such culture heroes is the Greek Prometheus, who is represented as having stolen fire from heaven, and certain very early legendary Chinese emperors, who are credited with the introduction of irrigation and other equally important advances. But, strictly speaking, all prehistoric inventors are unknown. Implements in those days, like ballads and legends of later times, simply came into being as the joint result of thought and labor on the part of many individual craftsmen.

Development of Implements

We come at last to the final question: How did implements develop? That is, once originated in simple, generalized forms,

how were they improved and specialized, first as hand manipulated contrivances and, during recent centuries, as parts of more and more complicated machines driven by non-human power? At first sight the story of development is nothing but the continuation of the story of origin. On closer examination, however, the two stages are seen to be somewhat different. One was presumably for the most part an unconscious trial-and-error process, the other is largely a deliberately planned, *i. e.*, an essentially conscious procedure, with which we are all more or less familiar. The problem of how present-day implements are modified to meet new requirements is seemingly so transparent as hardly to merit explanation. Are we not most of us in one way or another solving just such problems every day? What can be simpler when we are confronted with some unusual manual task than to use our tools in a different way or to devise some new and specially adapted tool? Let us consider a simple case.

Once upon a time, only a few thousand years ago, a man while trying to fashion a canoe out of a log by means of an ordinary axe discovered that he could work the wood to better advantage by turning the axe blade crosswise to the handle. The result was that the adze was born, a tool which is far more suitable for certain wood-working purposes than is the common axe. Now there is, most of us would say, nothing very mysterious about that transformation of axe to adze; yet that feat is a fair illustration of how all our implements and all our man-made things—the elements of material culture—have been derived by a series of generally slight modifications the one from the other. It is a simple and familiar process, that of growth or development by modification; and then again apparently it is not so simple. This fact of growth, or evolution, is one of the open secrets of the universe. We all recognize its reality in some sphere or other, but most of us refuse to recognize its universality. If, for example, we fully appreciated what is being done about new implements every day that passes, then the problem of the origin of implements would scarcely be a problem at all, for it would be clear that all inventions, from the latest television apparatus back to the first bowlder hurled at an approaching enemy, were arrived at by similarly easy steps or stages. More than that, if we really saw through this apparently simple act of creating a new implement—*i. e.*, a new cultural phenomenon—then the problem presented by obviously related organic and even inorganic phenomena would be greatly illuminated for us. We should then, at the same time,

realize that we inhabit a living or dynamic world and not a dead or static one.

If any one doubts that cultural phenomena arose in this way by gradual modification and adaptation, let him but read human history—any kind of history: religious, esthetic, linguistic, political, military, industrial. The conclusion will be the same. Later events grew out of prior ones and can be explained in no other way. The known history of inventions tells a similar story: our various appliances were not originated on the same date—as would have to be the case in a static world—but string along across the centuries and become simpler the farther back we go. No normal person will think of denying this; for in the world as we know it, how else could implements, or cultural phenomena, possibly happen? As it is, approximate dates can be cited for major inventions ranging back over the 5000 years of written history, and the unmistakable archaeological record continues the story on and on over as yet untold millenniums.

How can we be sure about this? It is very simple. In northern Spain, *e. g.*, there is a famous cave—the Castillo Cave—which was inhabited by man for several tens of thousands of years, long enough at any rate to lay down about forty feet of refuse, such as accumulates around any human habitation unless deliberately removed. The cave men here, as elsewhere, fortunately did not clean house and so their habitation floor ultimately rose so near to the ceiling that they themselves had to move out. During the long period of occupancy, extending over a good part of Pleistocene times, man came and went at intervals, so that the culture rubbish laid down occurs in the shape of no less than twelve or thirteen layers, separated by thin layers of sterile cave earth which drifted in during his absences. Excavation of this entire deposit, layer by layer, has supplied an indisputable record of the relative time of origin, as well as of the gradual improvement of numerous tools, weapons and ornaments made from stone, bone and shell. Together with these were also bones of the animals on which the makers subsisted and which changed in kind from time to time as the climate fluctuated. The oldest and best preserved implements found are naturally those made of stone, and by laying these out in the order of the layers in which they occurred we may read the story of implement improvements from the bottom to the top, like so many successive chapters in a book.

Unfortunately, the Spanish cave men departed from their old home

several thousand years ago, *i. e.*, before agriculture, domestication of animals, metallic implements and alphabetic writing were begun, so that any well rounded history of inventions has to be pieced out by the investigation of other culture deposits of later date found elsewhere, both inside and outside of caverns. This has now been done in both Europe and America and is well under way also in Asia and Africa. The result is that while the story of mechanical inventions is not complete in every detail, especially at the commencement end, professional archaeologists are today beginning dimly to see how it all happened. Fairly to convince others who may be interested of the reality of this implemental sequence would require an elaborate series of illustrations; but in place of such we may perhaps clarify what has been said by re-presenting a part of the discussion in tabular form. Taking for this purpose the six or seven earliest or primary forms of stone implements, let us see what recognizable modern specializations have been derived from them.

PRIMARY STONE IMPLEMENTS

Specially Selected or Artificially Produced, with Analysis of Their Varied Original Functions and the Specialized Implements Made, Mostly in Metal, to Serve Those Functions at the Present Time

Generic Form	*Functions*	*Specializations*
Hammerstone	Throwing	Slingstone, bole, bullet
	Clubbing	Club, nightstick, blackjack, bat
	Pounding	Hammer, maul, piledriver
	Crushing	Blacksmith's sledge, steam hammer
	Shattering	Flintknapper's hammer, rockbreaker's hammer
	Abrading	Stonecutter's hammer
	Grinding	Pestle
Perforator	Stabbing	Dagger, lancet, spear, arrow, rapier, bayonet
	Digging	Digging stick, planting stick, spade, shovel
	Punching	Brad awl, punch
	Sewing	Awl, bodkin, needle, stiletto
	Boring	Drill, auger, gimlet, bit, reamer
	Fastening	Pin, nail, screw, hook, buckle
Chopper	Cutting	Chopper, cleaver, axe, adze, gouge
	Hoeing	Hoe, pick, mattock
	Splitting	Wedge
Knife	Cutting	Knife, scalpel, scissors, razor, burin, sickle, scythe, reaper
	Shaving	Drawknife, spokeshave
	Sawing	Saws of various types
Scraper	Smoothing	Sidescraper; ordinary scraper
	Planing	Endscraper, chisel, burin, plane
	Shaving	Drawknife, spokeshave

Rubbingstone	Grinding	Upper mealing stone, mano, upper millstone
	Sharpening	Grindstone, whetstone, hone, steel
	Abrading	Rasp, file, lapidary grinder
	Smoothing	Sandpaper, sharkhide rasp
	Polishing	Ceramic polisher, lapidary polisher, burnisher
Anvil stone	Supporting	Anvil, mortar, lower mealing stone, metate, lower millstone

The Limits to Mechanical Invention

Having now some notion about the nature and behavior of the inventive process, from its slow and rudimentary beginnings down to its swift and complicated modern trend, the question naturally arises: What is the outcome going to be? Are we to continue progressing at the same increasing rate of speed as hitherto? In short, are there any limits to mechanical developments—to material culture growth?

In our enthusiasm it seems most natural to answer, No, there can be no limits; we are bound to go on progressing indefinitely! On second thought, however, one is disturbed by the realization that limits, both theoretical and practical, actually have been reached of late and that possibly we are approaching the time when human ingenuity will have to turn away from mechanical development to other neglected fields of endeavor. Communication, for example, has been made instantaneous and we cannot go beyond that. Transportation speed, particularly on land, has also reached very near to its practical limitations. It is no longer a question of building powerful enough engines, but a question rather of the endurance of the controlling human organism. In like manner there are obvious limits to the height of buildings, the length of bridges and the speed of industrial machinery. Lastly, in our efforts to curb and utilize the forces of nature we cannot go on indefinitely without running grave risks. Still more dangerous is it to impose our artificial schemes on the untamable aspects of nature. When, for example, a populous city chooses to grow up in a locality not by nature suited to the purpose, one may admire the spirit displayed but must at the same time feel dubious about such wilful courting of possible physical and economic disaster.

limits

Looking at the matter from another angle, it is apparent that limitation, or at least simplification, is already well under way. Hitherto tribes and nations have been developing independently and therefore naturally on somewhat divergent lines, and some old

civilizations like the Chinese long ago formulated precise rules for every undertaking, putting an end to hasty or radical innovations. Today trade and intercourse, as economic and political necessities, have already brought about international regulations respecting traffic, systems of measurement, scientific terminology, etc. A universal language, a universal coinage and a universal calendar are now being seriously considered. In short, international effort at standardization and simplification is on the way; and with it may be expected to disappear many near duplicate inventions, only those most serviceable being kept in use. Lastly, economic considerations are beginning to put limits to the immediate application of new inventions and improved methods because of the great cost of replacement.

The Social Consequences of Mechanization

In the course of the preceding discussion we have repeatedly broached, by suggestion, the possible as well as the actual risks connected with mechanical developments. Lack of space prohibits detailed consideration of this all important subject, but some slight amplification seems in order. The dangers referred to are real and ever present concomitants of advancing cultures everywhere; witness the periodic collapses of historic civilizations—Babylonian, Aegean, Egyptian, Greek, Roman, Indian, Chinese and many others less well known. In some cases the downfall is alleged to have been brought about by rude barbarians like the Scythians, the Mongols and the Teutons, but the real cause obviously lies elsewhere and deeper. Indeed, some historians would have us believe that the rise and fall of high civilization is as natural and inevitable as for the flower to bloom, to go to seed and to die. But while we need not accept the binding character of this or similar analogies, we must for the present content ourselves with a brief analysis of the good and bad factors involved in the great mechanization experiment.

The advantages of civilization are easier to name than to enjoy with absolute safety. By the invention of implements and the gradual mechanization of industry we have gained relief from much hard work and unpleasant drudgery; we have shortened the hours of labor, giving us time to spare for the pursuit of other interests; we have contrived to outrun the mammals, to outfly the birds and to outswim the fishes; and we have made life as a whole far easier

and more secure. Today only a few of the rodents and some of the insects dispute our sway. By merely turning a faucet or pressing a button several of the necessities and luxuries of life come directly to us—all we do is to pay the cash. In short, we have largely conquered both time and space; we have harnessed several of the forces of nature, with the general result that we live at a far swifter pace than did even our latest ancestors; and by doing this we have acquired in the bargain a new and effective method of procedure, for we have learned how, by organization and specialization, to reach even greater heights of accomplishment. What then is wrong?

The question has been answered many different ways in particular cases, but few if any of these explanations have gone to the heart of the matter. The trouble started, of course, at the moment when man rebelled against nature and succeeded in outwitting her. By this is meant simply that when man took up with implements he did something unique and therefore at least partly contrary to nature as ordinarily understood and consequently something fraught with risks. At the start it was simply a stick or a stone that separated man from nature, but today, in some countries, more than half the inhabitants live in large cities, all but out of touch with the elemental sources of life. As city dwellers we are less and less directly dependent on nature, but at the same time more and more dependent upon one another; and here at once is the first source of difficulty, because human nature is rather less dependable—or should we say less well understood?—than is nature in the larger sense. Stated in another way, man, through the origination and development of his material culture, has created for himself a more or less completely artificial environment and thereby has placed himself in a corresponding measure out of direct reach of nature's molding influences—out of reach, that is, of the normal forces that make for natural selection and the survival of the fittest. When the seasons in their course change our environment, or when we choose to change it by a journey to the arctics or the tropics, we do not wait to change our bodily constitution; we merely change our type of food and clothing. In proto-human days our ancestors, like the animals of today, had to migrate (perhaps hibernate) or die, unless or until by a very gradual bodily modification through selection they became adapted to the new surroundings. Our present scheme of quickly changing our cultural equipment instead of our bodily constitution has many obvious advantages and therefore real survival values;

but the attempt thus to speed up and improve upon nature places far greater responsibilities upon us and the normal result is that we often err and come to grief.

The historical events which appear to demonstrate the weakness of high civilization are too numerous to be detailed in full, especially as they are already to some extent well-known subjects of daily discussion. Moreover, exhaustive recital of symptoms is scarcely necessary once our attention has been centered on the causes producing them, after which the defects in question can no longer be so real as they originally seemed. At best, however, the various hazards, past, present and to come, are real enough to require our constant attention, both public and private, inasmuch as they are sociologic as well as biologic.

First, as to the individual or mainly biological aspect. When man took up with implements, *i. e.*, with artificial or indirect means of coping with the problems of existence as presented by the natural world, he obviously separated himself by that much from the rest of creation. He is no longer competing on fair and equal terms and is consequently no longer a true animal; but he remains nevertheless subject to some of the laws governing animal organisms. Now it must be apparent that the use of implements, the resort to clothing and to heated or cooled habitations, the crowding into partly sedentary and eye-straining indoor occupations, the movement from place to place and also the procurement of many of our wants and pleasures without bodily exertion, the excessive refinement of our foods together with the equally excessive refinement (or the reverse) of our general surroundings—one and all constitute a direct breach of faith with nature. If, therefore, nature appears to take her revenge we cannot with justice complain. Nervous breakdowns, occupational diseases, tuberculosis, weak hearts, defective eyes and teeth are no more than we should expect under the circumstances. And if, in addition to all this, we nurse along to maturity, by medical skill, those individuals who would normally have died in infancy, we are obviously at fault in blaming nature for ultimately asserting her rights. The human body is presumably as plastic as ever, but if we seek to bring about in a lifetime or less such radical adjustments as nature could scarcely be expected to accomplish in a thousand years occasional disaster seems a foregone conclusion.

On the social side the price we must pay for progress is no less inevitable. Industrialism has brought about the removal of more

than half our population from its ancient natural home in the country and the herding of it into crowded artificial communities—a change such as no other similar group of complex organisms could survive. Many of the migrants have visibly bettered their opportunities by the move, but the majority have only exchanged all manner of absorbing handicrafts for that of machine tender, repeating a few set motions involving little creative effort and affording little stimulus beyond the wages received. Almost all have jeopardized their economic security; for while in the country they were relatively self-dependent and subject chiefly to the occasional whims of nature, they are now subject also to the ever fickle whims of their fellow man and his new inventions, which periodically deprive many of them of their livelihood. The new Hoover dam, it is said, will yield power equivalent to that of over 20,000,000 slaves working day and night; and this is only a prospective example of many historic illustrations of how the world's workers temporarily suffer by the introduction of new means of production. The natural results of all this integration or intensification of life are social disorders of all kinds: strikes and lockouts, vice and crime, new epidemic diseases—some of them fatal to primitive people, a heavy toll of accidents connected with the use of machinery, and, finally, the general weakening or effeminization of the human spirit, as exemplified by the more or less necessary loss of much of the old-time independence and sturdy self-reliance which characterized, for example, our American pioneers. In this connection it is scarcely without significance that our farmers are the last group to organize for purposes of cooperation in the economic struggle.

In conclusion, it is fortunate that time does not permit us to prescribe for the ills of civilization, if ills they really are. Most of our city dwellers appear to regard their advantages as worth all the risks involved; and doubtless they are essentially right, because urbanization in some form is the only logical outcome of our cultural experiment. Mankind has set out on a great adventure and, risks or no risks, cannot turn back. The Gandhis of the world can scarcely arrest permanently the process of industrialization. We can only ameliorate its undesirable features by education through more intimate organization. To this end the study of history and of archaeology has much to contribute, for once we become familiar with the entire past of human development we should be in position effectually to direct our future course.

Summary

Under cover of presenting some of the salient facts known about the origin and development of tools and weapons the writer, prompted by the intimately related cultural crisis of the day, has ventured some of his personal views concerning the nature and significance of human material civilization as a whole. Without going the length of summarizing in detail all that has been said, the attempt has been made to define the nature and function of implements, to account for their origin, and to describe the actual steps in the process of their evolution, as determined by archaeology. The process of mechanical invention, begun about a million years ago, has been shown to move forward with ever increasing speed until now, when there are distinct signs of its slowing up or of having run its course as the dominant medium of material progress and of being perhaps on the point of handing the torch over to chemistry. This last is suggested, for example, by the recent substitution of rayon for silk. At any rate, the general course of industrial development hitherto has been from hand labor to machine production and from mechanical toward chemical processes; in other words, from essentially instinctive and crude muscular exertion to ever more deliberate and refined intellectual effort in utilizing the available forces of nature for the satisfaction of our varied needs and desires. Throughout the discussion the emphasis has been placed on the cultural *process* rather than on the multiplicity of its details. This process has been explained as a new method—the human method—of conducting the struggle for existence and also as the most easily understood illustration of the more or less obscure general theory of evolution or the origin of living phenomena by growth with modifications. In this connection it has been pointed out that a study of the history of mechanization reveals few if any absolutely original contrivances that were not essentially the results of gradual transformation or combination of older inventions; that in reality sports, mutants or leaps are as rare among artificial (intellectual) phenomena as among natural phenomena. Progress in the former case is regarded as unthinkable except in terms of orderly sequence, process, or continuity, though the added increments that proclaim advance may not thereby be fully explained. Final explanations of this, as well as of the driving force and the ultimate goal of culture, may be left to the philosophers. Brief consideration has been given finally to the

serious biological and social consequences growing out of this new and self-directed mode of life, with a view to indicating their naturalness and to suggesting the lessons we must learn from them. There remains only to add, in the words of another, that the only cure for the ills of civilization is more civilization.

BIOCHEMISTRY AND THE WORLD TODAY*

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Man is primarily interested in man. He is secondarily interested in his environment, but his interest in his environment is largely selfish, for he knows full well that he can best advance his own welfare by modifying the environment in which nature has placed him.

We live on a globe called the earth which is only one of the minor planets in our solar system. We know that our solar system forms an insignificant fraction of the greater stellar galaxy, and only recently we have been made aware of the fact that our galaxy of stars is only one of some thirty million similar galaxies distributed more or less uniformly through space but separated from each other by distances of the order of one and a half million light years.

Our environment outside of the earth is fixed—immutable. Nothing that man has done or can do will affect the destiny of the stars. Man is not the lord of creation, he is not even the master of the earth! This insignificant globe upon which we live is some 8000 miles in diameter. In order to explain the physical properties of this globe geologists have concluded that the earth is composed of a central core, or centrosphere, several thousand miles in diameter. This core is surrounded with a shell or athenosphere which is probably several hundreds of miles thick, and this in turn is surrounded with another thin shell, the lithosphere, which is probably only forty or fifty miles in thickness. Above the lithosphere lies the atmosphere, a relatively dense mass of gas at the point where it is in contact with the lithosphere and becoming more and more attenuated until it merges into the vacuum of space perhaps several hundreds of miles above the earth's crust.

Man's environment is not the earth as a whole. It is only that minor fraction which lies very close to the junction between the upper part of the lithosphere and the lower portion of the atmosphere, the portion which McKibbin calls "The Life Layer of the World." Man has as yet penetrated only a little over a mile into the solid

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portion of the lithosphere, he can descend only a few hundred feet beneath the surface of the oceans, he can ascend only a few thousand feet into the atmosphere. He is a prisoner on a plane—excluded from the control of the heavens above him and from exploring and exploiting more than an insignificant fraction of the earth beneath him.

This plane then in which man lives—his feet on the surface of the lithosphere and his body surrounded by the atmosphere is the environment in which the average man is most profoundly concerned.

Eons ago this same geometrical plane existed, but what a different environment it would have proved to be had man suddenly been placed upon it—a barren waste of rocks—sand—gravel—and water, inhospitable to the last degree. And had life in the form of the lower plants and animals not appeared—and had these in turn not been succeeded by the higher plants, that plane today—eons later—would still be a barren waste of rocks—sand—gravel—and water, a true soil would be absent and the only change wrought by the ages would be the accumulation of more and more of the smaller fragments of detritus at the expense of the larger rock masses.

The lower forms of plant and animal life made possible the higher plants of today and these in turn created an environment which permitted man to inhabit, to explore, to exploit and to proclaim himself master of the "life layer of the world." We may slightly modify it, but we are truly "creatures of our environment."

And the environment upon which we are so absolutely dependent is a *living* environment! The soil is teeming with life, millions and millions of bacteria, infusoria and fungi in each cubic inch. It is these organisms which prepare the earth for the growth of the higher plants and it is these in turn which have prepared the earth as a habitat for the higher animals, including man.

Chemistry is the science which deals with the nature of matter and the transformations and combinations which atoms and molecules undergo in building up the diverse kinds of substances which comprise the material universe. Because of the enormous scope of the field, special groups of chemical subject-matter have been more or less arbitrarily set off from each other, but no field of chemistry possesses a greater range of subject-matter, a greater diversity of problems, a greater necessity for new and ingenious technique or a greater opportunity of service to mankind than the field of biochemistry, the chemistry of living processes, for it is through the biochemical trans-

formations taking place in our own bodies that we are enabled to live in an environment which itself has been created by biochemical reactions.

Biochemistry—the chemistry of living processes.—The same fundamental principles which underlie the fields of general chemistry, inorganic chemistry, organic chemistry and physical chemistry are the fundamental principles which regulate the chemical processes taking place in living organisms. Biochemistry has been variously defined by different workers. I have preferred to define it as "a field of science devoted to the study of the natures and reactions of those compounds found in living matter and the role which these compounds play in living organisms," recognizing full well that with the eventual accumulation of facts this imperfect definition may be replaced by the more positive definition, "a field of science yielding an interpretation of the reactions of living organisms in terms of physics, chemistry and mathematics."

Eons ago somewhere in the vast waste of rocks, sand, gravel and water the first primordial protoplasm came to be. What factors were concerned, what forces were involved in this momentous occurrence, we shall probably never know, neither shall we ever know what form of life this primordial protoplasm represented. One fact, however, seems relatively certain and that is that the energy relations of these early life forms differed widely from those of the higher plants and animals of today. These early forms of life appeared upon an inorganic world, and the transformations of inorganic chemical compounds must have provided the vital energy of these early inhabitants of the "life layer."

Today we find upon the higher peaks of Alpine heights, bacteria which subsist upon nitrogenous compounds brought down by the rain and snow from the heavens and securing their energy by oxidizing ammonia to nitrous and nitric acids. In the sulfur deposits of volcanic areas other bacteria are present which utilize the energy liberated by the oxidation of elemental sulfur to sulfuric acid, and our own great iron deposits of the Mesaba and Cuyuna ranges represent the remains of untold myriads of bacteria which utilized for their "food" the traces of iron bicarbonate in solution in the waters, oxidizing it to iron oxide, and later the iron residues remaining in their dead bodies were consolidated into our great iron ore deposits of today. The worker in the steel mill who shapes the crank-shaft of your automobile probably would be surprised to learn that his chief

raw material has been made possible by a biochemical reaction. Even today in many places where conditions are favorable this ancient process of iron accumulation is actively progressing.

Such lower forms of life as these slowly but surely transformed the barren waste of rocks, sand, gravel and water in such a way that higher forms of life became a possibility. Just when, or where, or how, the new forms of life came to be, again we shall never know, but somehow, somewhere, an all-important chemical compound originated within a living organism. This compound transcends in importance any other chemical compound known to man, chlorophyll, the green pigment of the plants, for through the peculiar energy-absorbing and energy-transforming properties of chlorophyll the fixation of the energy radiated by the sun became possible. No longer was life limited to those spots on the earth's surface where ammonia occurred in solution in the waters, where elemental sulfur existed or where an abundance of soluble iron salts were present in a pool or sluggish stream. The great, fundamental biochemical reaction was an accomplished fact.

$$6CO_2 + 6H_2O + 677.2 \text{ Cal.} = C_6H_{12}O_6 + 6O_2$$

Six gram molecules of carbon dioxide plus six gram molecules of water plus 677.2 kilogram calories of energy yields one gram molecule of glucose plus six gram molecules of oxygen, the process of photosynthesis.

Carbon dioxide was abundant in the atmosphere and through the agency of chlorophyll and in the presence of water and sunlight the chlorophyll-bearing organism was able to fix in the form of organic compounds the energy radiated by the sun and to store this energy for the use of future generations. The power station of life had been established!

All of the carbon in coal, in peat, in our forests and in our own bodies is directly or indirectly derived from the sugars which are the resulting product of this great fundamental biochemical reaction.

The second great fundamental reaction of biochemistry is the reverse of the first:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 677.2 \text{ Cal.}$$

One gram molecule of glucose plus six gram molecules of oxygen yields six gram molecules of carbon dioxide plus six gram molecules of water plus 677.2 kilogram calories of energy, the process of respiration.

By this reaction the sunlight energy reserve built up in the green leaves of the plants becomes available for the use of both plants and animals.

All of the higher plants and the animals, including man, secure the energy for their vital activities through this process of respiration, the only difference being that the higher plants are able to build up through the agency of chlorophyll and in the presence of sunlight those chemical compounds which they later "burn," whereas animals are dependent upon plant sources for the fuel which keeps their bodies warm and their vital activities functioning. Viewed from this standpoint the reactions of plant biochemistry are more intricate, more baffling and more important than are the reactions characteristic of animal cells and tissues, since in the plants we study not only those reactions which utilize energy but also the much more important reactions involving the fixation of energy.

The civilization of which we are a part has been referred to by various writers as "the age of steel," "the age of chemistry," "the age of cellulose," "the age of concrete," or "the age of industry." It might better be called "the age of energy" for the modern industrial and mechanical civilization requires prodigious expenditures of energy. It has recently been estimated that in the colonial period of American history the amount of mechanical power available in the form of human labor, horses and oxen, and the simple machines of that day was equivalent to approximately three man power, or concretely to three slave power per capita. That is, all of the requirements of each person could be met by the work which could be accomplished by three slaves. Since colonial days the requirement for energy expenditures has increased by leaps and bounds so that today the energy requirement of our modern civilization is equivalent to 165 slave power per capita. This means that the average American home of five persons has at its beck and call the equivalent of 825 slaves.

A small fraction of this energy is derived from water power and from the winds, but the great bulk is the resultant of burning the coal and oil which have accumulated in the earth as the product of the biochemical reaction of photosynthesis in bygone geological ages.

Every day we plan how we can utilize tomorrow more and more energy than we are using today. Some day the reckoning will come—probably not during our lifetime, nor even in our grandchildren's

lifetime, but surely and soon, as time is reckoned in history, the human race will discover that the enormous reserves of energy have been exhausted, that our inheritance from the ages has been largely and irrevocably wasted and the environment of man may thereby be so altered as to be the deciding factor in the type of civilization of that day. We are drawing upon a capital which can never be replaced, and even at our present rate of energy utilization the world faces an energy bankruptcy in less than two thousand years. The human race will have modified for the worse one factor of its environment.

Many are still living who have seen the axe and the torch advancing across the Alleghenys, through the wooded areas east of the Mississippi, through the forests of the Lake States until today the forests of America are only a remnant of the "inexhaustible" forests of the colonial days. The great industries of pulp and paper, of nitrocellulose, rayon and lacquers utilize as their raw material, cellulose, a biochemical product formed in the laboratories of the green leaf. The same statement holds true for the modern dyestuffs industry, excepting that here the basic raw materials are largely derived from fossil forests. In the last analysis, the more important industries of the world utilize biochemical products as their raw materials.

We are inclined to magnify the accomplishments of man, to extol the achievements of our modern chemical industry, but in most instances we are in reality only modifying or adapting to our special uses certain features of a biochemical environment. We enthuse over our successes in the realm of nitrogen fixation and point proudly to the fact that, in 1927, 1,620,000 tons of fixed nitrogen was produced in our chemical factories, forgetting that this apparently enormous tonnage is less than one ten-thousandth part of the nitrogen brought down to the earth by the rainfall alone and infinitely less than the approximately nine-billions of tons of nitrogen fixed each year in the soils through the biochemical activity of microorganisms. Quietly—continually—and unknown to most of us the microorganisms in the soil, the various elements of the plant kingdom and many elements of the animal kingdom keep the even tenor of their ways, building up and maintaining our environment in the "life layer."

The retreating front of our forests has been closely followed by fields of waving grains. Long ago man selected certain seed plants as especially suitable for use as food sources and through generations these plants have been grown, cultivated and improved by wholly empirical methods. Only recently has the scientist undertaken a

study of the nutritional requirements of both plants and animals and of methods whereby new and improved varieties can be produced. Within less than a hundred years the sugar beet has been developed from only a fairly sweet root into one of the principal sources of the world's sugar supply. Within the scientific lifetime of workers still active in our own agricultural experiment station, the northern limit for corn production has advanced from the southern border of this state until today it is approaching the shores of Lake Superior. It may well be that another generation will see the northern limit of profitable corn production advance across the International Boundary. We have seen the average production of wheat increased from six to ten bushels per acre in the manorial period of England to approximately thirty bushels per acre today, largely due to an increase in the knowledge of the factors necessary for adequate plant nutrition. Pineapple growing in Hawaii has become a profitable industry because of the discovery that minute traces of iron are necessary in order that chlorophyll may develop in the leaf cells. The increased production of our dairy herds and poultry flocks in no small measure reflects the researches of the biochemist in the field of animal nutrition.

These and many other similar examples are largely the product of our agricultural experiment stations where many workers trained in the various fields of science are intent upon improving the biological factors of our environment. In nearly all phases of the work the biochemist plays an important although perhaps a minor role. The scientific agriculture of today has been made possible certainly not by biochemists alone, but equally certain by biochemists working hand in hand with other specialists of science to increase crop production and to utilize the raw materials grown in nature's laboratory.

But perhaps enough time has been devoted to man's environment. Perhaps enough has been said to prove the thesis that it is largely a biological environment in which the all-important activities are biochemical reactions and that if for only one short year the fundamental biochemical reaction of photosynthesis should fail to be, all of the higher forms of animal life and most of the higher forms of plant life would vanish from the earth. If that reaction should fail altogether, within a very few years the surface of the earth would again be reduced to a barren waste of rocks, sand, gravel and water.

Man is primarily interested in man. The human body is an intri-

cate biochemical laboratory where a multitude of diverse chemical compounds and chemical reactions occur simultaneously and the integrated expression of all of these diverse reactions is what we have chosen to call "life." Many of these reactions proceed at a very exactly regulated velocity with slight deviations from the normal producing pathological conditions and major deviations producing death. Thus, for example, the metabolism of the body, the "burning" of sugars, fats and proteins for energy or warmth is regulated to a large degree by the chemical compounds secreted by the thyroid gland. Dr. Kendall, biochemist at the Mayo Foundation, isolated several years ago a potent principle of the thyroid in the form of thyroxine, a white crystal powder containing 65 per cent of iodine. Probably not more than 0.5 grain of iodine combined in the form of thyroxine is present in the body at any one time, yet this small amount is essential as the regulator of our biochemical activities. In the event that the thyroxine supply fails, either through disease of the thyroid or from the lack of adequate amounts of iodine in our food, the metabolism of the entire body is disrupted, the biochemical reactions slow up, the body undergoes infantilism as to form and function and mental inadequacy or idiocy results.

On the other hand, if the supply of thyroxine produced by the thyroid exceeds the normal optimum, then the various biochemical reactions are accelerated and the tissues of the body are literally "burned up" during the lifetime of the individual.

This discovery of the nature of thyroxine and of its physiological function has proved of great value in modern medicine. It has enabled the physician to bring back to normal well-being and a life of usefulness many individuals who otherwise would be a burden either upon relations or upon organized society.

But thyroxine is only one of probably many hormones which act as regulators of the physiology of the human body. It is the aim and desire of the biochemists to search out these important chemical compounds, to ascertain their nature and if possible to prepare them in the chemical laboratory. Thus adequate amounts will be available for the use of the physician. Thyroxine has recently been synthesized (built up) in the chemical laboratory.

The first hormone to be isolated and studied was epinephrine, or as it is often called, adrenaline. Abel of Johns Hopkins University first identified epinephrine as a compound secreted by the suprarenal glands which are situated close to the kidney. It has the property of

powerfully contracting the walls of blood vessels, thus providing a means whereby blood pressure can be greatly and rapidly increased in cases of emergency. It is this hormone which is commonly used in those cases where the newspapers report that "an injection into the heart caused the heart to begin beating again and brought the dead back to life." Extremely minute amounts of epinephrine are present in the body at any one time, and the injection of $^3/_{100,000}$ of a grain will produce a pronounced physiological response. Epinephrine has proved a boon to surgeons, in that its use has made possible the control of bleeding while performing many surgical operations.

The adrenal gland contains a second hormone, the nature and properties of which are still somewhat obscure. We have recently learned, however, that its absence, due to a pathological condition of the adrenal gland, is associated with the rare, but hitherto invariably fatal, Addison's disease. When this hormone has been isolated in a pure state and later synthesized by the chemist, the cure or at least alleviation of one more dread disease will have been accomplished.

In 1923 the Nobel prize in Medicine was granted to Drs. Banting and MacLeod of the University of Toronto. These investigators were fully aware of the common knowledge that the disease, diabetes, was due to pathological conditions involving the pancreas gland. They, however, succeeded where others had failed, and isolated from the normal pancreas glands of animals a hormone, insulin, which has brought relief and hope to thousands of persons suffering from diabetes. Insulin is secreted in a group of cells associated with the pancreas gland. The presence of insulin in the blood stream and tissues enables the body to "burn" sugars and fats in the normal physiological manner, whereas in its absence the sugars and fats are only imperfectly burned, producing products which in some instances are highly toxic to the human organism.

Within the last few years the search for other hormones has proved very fruitful. The sex glands have been shown to contain hormones which control many important body functions. The same holds true for the secretions of such glands as the pituitary and the hypophysis.

It is fortunate for us that man is an integral part of the animal kingdom. Apparently many of the vital functions of other animals are controlled by the same hormones which control the vital functions of man himself. Thus, for example, we use the thyroid glands

sheep for the isolation of thyroxine to correct a deficient thyroxine supply from our own thyroid glands, we use the pancreas of cattle as the source of insulin in treating human diabetes and the dread disease, pernicious anemia, has yielded in a large measure to the potent principle contained in the liver of domestic animals.

Undoubtedly there are other hormones, of the nature and function of which we are at present entirely unaware. Many of the preparations which have been made are exceedingly potent physiologically, but equally exceedingly impure. Much work still remains to be done before the final goal of the biochemist is reached, an adequate amount of all of the vital hormones available to every physician. When that day arrives, medicine will take a long stride ahead, for these regulators of body functions play an enormous role in our physical, mental and moral well being.

The hormones appear to be solely of animal origin and to be built up *de novo* by the cells or tissues of the organism whose physiology they control. This is not the case with the apparently equally important group of biochemical compounds which we call the vitamins. These appear to be either a primary plant product formed in the plant cells but essential to the well being of the animal which utilizes these plant tissues as food, or else to be a modified plant product wherein the plants furnish a provitamin which in the animal body is converted into the true physiologically active vitamin. The function of the vitamins in the economy of the plant is wholly unknown, but the absence of the vitamins from the diet of animals, including man, produces such striking effects that the vitamins may well rank as of equal importance with the hormones.

The vitamin literature all dates since 1900. For many years a peculiar disease known as beri-beri had decimated the Japanese navy. This disease was particularly prevalent when the long cruises were undertaken. The cause of the disease was at last traced to the food supply, polished white rice, and when this was replaced by the brown rice from which the bran had not been removed, beri-beri no longer occurred. Somewhat later a Dutch physician, Eijkman,* produced what appeared to be experimental beri-beri in fowls and cured it by feeding rice polishings. Evidently, therefore, the brown pericarp of the rice kernel contained a potent substance necessary for the normal function of the human organism, the absence of which produced illness and death. We now know this substance as vitamin

* In 1929 Eijkman received the Nobel Prize in Physiology and Medicine.

B. We know the physiological symptoms which are manifest when vitamin B is absent from the diet, we have classified the foodstuffs into those which are rich in vitamin B, poor in vitamin B or those from which vitamin B is absent, but it has not as yet been possible to isolate in a pure form this elusive principle. Concentrated preparations have been made, thousands of dollars have been expended in the search, but because of the extremely small amounts which are present in any given material and the difficulties involved in its separation, we are still far from the ultimate goal of the biochemist, its isolation, determination of its structure and its artificial production in the chemical laboratory.

To those of us in America, with our abundant and varied diet, these problems of vitamin research often appear as academic and impractical. Perhaps no more striking illustration of their importance to multitudes of our fellow men can be found than a few paragraphs quoted from a little book entitled, "Good Will on a Coral Strand," by Henry Page, M.D.

You may picture Dr. Page as a physician ministering to the Moros in the Sulu Archipelago, Philippine Islands. He writes.

"Have you ever been in a baby dispensary? If so you will know what I mean when I call it the most joyous heartrending place in the world. This was particularly true of my Moro dispensary. In spite of my childhood dreams of vileness on coral strands, I found these babies so much like other babies I had known that at once my heart warmed to them. I learned very quickly that the differences of civilization are not apparent until after babyhood ends.

"There was very little that was joyous about the dispensary at first. It was mostly heartrending, for only the very sick ones came, their mothers bringing them evidently because Kush had told them of my magic—in which they only half trusted. They knew that death was near. To them I was a last forlorn hope. Those poor little mothers made me regret that I had ever decided to study vileness. They never reproached me for my failures, but their eyes haunted me, just as the eyes of a deer that I shot twenty years ago still haunt me. There is something about an animal in pain that is distressing just as were those mothers who were dumb and patient like animals. It got horribly on my nerves, for I could not find out why the babies died. I could not help them. I felt like a criminal, an impostor. The Spanish had described the malady. They called it 'alferacia,' and they truthfully remarked that its mortality rate

runs close to 100%. The kiddie would be well and apparently thriving, until it suddenly developed a high fever with severe digestive disturbances. In twenty-four hours it had wasted away, and after the third or fourth day its visits ceased. I never asked what had become of it. I knew. Every chemical, physiological and bacteriological test was negative. It was a mystery and I did not have the key. Whether it was professional pride or a more exalted emotion that stirred me I cannot tell, but I finally reached the point where the cure of those little creatures meant more to me than any interest I had known. I remember how excited I was on one occasion when one little fellow smiled and cooed at me. It was like a burst of sunshine through the clouds, and I was actually radiant until two days later he died while I looked on in utter helplessness and hopelessness.

"The months passed by and I had not saved a single life. The dispensary would have been closed long since for lack of patronage had it not been for Kush, my persuasive and tireless 'attachor.' And then the great event happened.

"How well I remember that day, Saturday, June 16, 1910. A little wasted man-child lay across my lap. I could feel his hot body burning me wherever it touched. As I put my fingers to his lips, his tongue, hard and dry, pushed them away. His little breast rose and fell in short jerks, and through his tiny ribs I could almost outline the whole heart as it desperately fought for life. I had tried everything I knew, and this was the result.

"It was my turn now to look for help and I, like the tiny wild mother who watched me in silence, did not know where to turn. It must have been this mutual feeling of impotence that, against my will, drew my eyes to hers. I did not often look at the mothers; what I saw hurt. But on this occasion it was different. She could not have been more than thirteen years of age, and I doubt if she weighed fifty pounds. As I glanced at her half naked body I saw that above she was thin beyond description, while below she looked well nourished. Reaching over I pressed my finger over one of her shin bones and it sank in half an inch. In my excitement I put the baby on the floor, and through my stethoscope I listened to her heart. And then I did a silly thing. I laughed.

"It was so absurdly simple. The mother had beri-beri. The child was nursing at the breast of a mother who had not enough vitamines to save herself, much less her child. I laughed just as

Columbus must have laughed when his lookout cried 'Land Ahoy'—just as Newton laughed when the apple dropped—just as Watt laughed when the tea-pot clicked—just as every one laughs when from darkness he comes unexpectedly into the glorious light. I laughed, and it was a laugh of joy—an explosion of taut nerves suddenly relaxed. The mother smiled too. I had never before seen a Moro mother smile. And she did well to smile, for her life, and the life of her babe, and of every other mother's babe that came to me thereafter, was saved from that disease, alferacia—except, of course, those who came too late."

The revelation of the necessity of vitamin B for health and well being initiated a new era into the science of nutrition. The discovery of other vitamins followed as a consequence of the stimulation of research in this field. Scurvy, the dread disease of the arctic explorer and the seafarers of a generation ago, was shown to be due to a vitamin deficiency, lack of vitamin C. Rickets, the almost universal disease of childhood, can be prevented or cured by adequate amounts of vitamin D in the diet. Certain fats and oils, and yellow roots have associated with them either the provitamin, carotin, or the fat-soluble vitamin A which is necessary for normal growth and which apparently protects the body against infections and disease, and only recently the baffling disease, pellagra, has been shown to be due to the absence of adequate amounts of vitamin G.

The biochemist has demonstrated conclusively the existence of six vitamins, and it is highly probable that later work will add several others to the list. In the case of only two vitamins, vitamin A and vitamin D, do we have any clear picture of the nature of the compound or the method by which it is formed in nature.

Vitamin A is apparently formed in the animal body from carotin, a substance widely distributed in nature, present in all green leaves, and familiar to all of us as the yellow pigment of carrots and butter. A series of remarkable researches have within the past year or two elucidated the formula of carotin and have shown that it bears a striking resemblance to one of the constituents of the chlorophyll molecule. Somewhere in the animal body, possibly in the liver, the carotin molecule is broken in the middle, at one of its many double bonds, and with an alcoholic —OH group added in this position it becomes vitamin A. The structure of vitamin A is now so nearly assured that we may confidently expect the synthesis of this important vitamin in the not distant future.

Vitamin D apparently arises from the action of ultraviolet light upon one of the complex higher alcohols, ergosterol. Windaus received in 1929 the Nobel Prize in Physiology and Medicine for demonstrating that ergosterol, when exposed to ultraviolet radiation, is transformed, wholly or in part, to vitamin D. Bills has recently announced a similar transformation when nitric oxide acts on ergosterol in the absence of oxygen. Apparently, in at least three laboratories, the pure vitamin D has been isolated in crystalline form, but its exact chemical structure still remains to be determined. Because of the complexity of the molecule its ultimate synthesis in the chemical laboratory is beset with great difficulties.

Even granted, however, that the chemist will eventually be able to determine the exact structure of all of the vitamins and to prepare them artificially in the chemical laboratory, much important work for the biochemist still remains. The question as to why one one-millionth of a gram of a chemical compound, with a particular configuration, is so necessary for the normal functioning of our vital processes still calls for solution. We know that vitamin D controls in some manner the calcification processes in our skeletal structure, but we are still ignorant of the physiological and biochemical mechanism which associates an almost infinitesimal amount of a complex higher alcohol with the metabolism of phosphorus and calcium, or similar amounts of the other vitamins with their specific functions. Problems such as these offer great difficulties and equally great rewards to the biochemists of the future.

The science of nutrition thirty years ago was a simple story. It was recognized that adequate amounts of protein must be eaten in order to provide the tissue-building elements. If, in addition to the protein, an ample calorific intake was secured, then it was thought that satisfactory nutrition would result. The calorific intake was easily provided by carbohydrates and fats.

The discovery of the vitamins and the demonstration of their importance in nutrition showed the fallacy of the older views. Within the past two decades the old theory that all proteins are equally valuable as tissue-building elements has been overthrown, and we now know that protein "quality" is just as important a factor as is protein quantity. That is, certain of the chemical compounds, the so-called "amino-acids," from which proteins are built up are essential for both growth and maintenance. If only one of these essential amino acids is lacking from the diet, growth may cease and starvation

result, a true starvation in the presence of what appears to be an abundant food supply.

Problems of essentially equal importance to those of the proteins and the vitamins have recently been opened by studies of mineral metabolism. It is recognized that many persons, especially children, are inadequately nourished with respect to certain of the mineral elements. The essential nature of even such unusual elements as copper and manganese has been fairly well demonstrated, but in the face of such demonstration the biochemist of the future must decipher the nature of the physiological functions which these elements control.

Sixty-five per cent of the human body is water. Until recently an altogether disproportionate amount of attention has been paid to the solid constituents of the body, the water relationships being correspondingly neglected. Abundant evidence is now available that a very considerable amount of this water is intimately associated with the body tissues in such a firm union that it may be regarded as an integral part of the living protoplasm. The physical properties of such "bound" water may be very profoundly altered, its ability to act as a solvent may be greatly lessened or may wholly disappear.

Slowly but surely methods are being found which will serve to differentiate such "bound" water from the "free" water present in cells and tissues. Such studies as have already been made point to the conclusion that many of the problems of growth, disease and senescence are intimately associated with the ability of the tissues to "bind" water. The physician is slowly but surely bringing disease after disease under control, and it is not an idle dream to look forward to a day when disease will be looked upon as a social crime and as the result of ignorance or carelessness. Even in such a Utopia we would, however, still have the problems of old age. All biochemical systems tend with time toward a lessened water-binding capacity, and we, as we pass from youth to old age, are no exception.

The search for the philosopher's stone and the elixir of life motivated the chemists of the medieval period. The transmutation of the elements and the unity of the nature of all matter is today no longer questioned. May we not at least be permitted to dream of a day when the elixir of life shall become a reality. If that day should ever come, I predict it will have been brought about in a large measure by a full and complete knowledge of the relationships and forces which exist between water and the other elements of the human body.

Biochemistry and the world today—the field of study is almost limitless. The workers are few, our knowledge and equipment are inadequate for the elucidation of many of nature's secrets. A few facts have been presented, a few problems have been selected more or less at random from the many which must ultimately be solved. And they will be solved! Science advances not so much by theorizing as by intensive and persistent laboratory research; little by little the available facts accumulate until some outstanding thinker collects them into a completed picture. We may well pay heed to the words of one of these. Pasteur recognized full well the role which research plays in an educational and economic program. He says,

"Take interest, I implore you, in those sacred dwellings which one designates by the expressive term, laboratories. Demand that they be multiplied, that they be adorned. These are the temples of the future—temples of well being and happiness. There it is that humanity grows greater, stronger, better."

LIST OF MISSING PERSONS

Can You Help Us Locate These Members?

Name	*Chapter*	*Last Known Address*
Fleming, Allan James	McGill 1927	Physics Dept., McGill University
Fleming, Harry C.	Nebr. 1909	221 Pratt Bldg., Kalamazoo, Mich.
Fleming, John D.	Wash. 1913	3954 St. Louis Ave., St. Louis, Mo.
Fletcher, Arthur R.	Columbia 1911	
Flick, J. Theron	Syracuse 1913	Princeton University
Florance, Edwin	Columbia 1921	
Flothom, Paul G.	Nebr. 1922	Col. of Med., U. of Nebr., Omaha
Flynn, James Howard	Mich. 1909	Burroughs Adding Machine Co., Detroit, Mich.
Foehl, Edward Albert	Md. 1928	2728 12th St., N. W., Washington, D. C.
Foley, Mrs. J. W. (Ellen S. McCarthy)	Cornell 1907 Ill. 1909	4 Hackensack Ave., Ridgefield Park, N. J.
Follin, James Wightman	Mich. 1914	Narberth, Pa.
Foltz, Joseph P.	Mo. 1924	Dearborn, Mo.
Foord, Alvin George	Chicago 1917	Colfax Hospital, Colfax, Colo.
Forbes, Henry	Minn. 1922	
Ford, Carlotta Marks	Ill. 1911	1105 Oregon St., Urbana, Ill.
Ford, J. L.	Purdue 1920	839 Majestic Bldg., Detroit, Mich.
Ford, Walter Stebbins	Cornell 1911	Cornell University, Ithaca
Fort, Edwin John	Cornell 1893	1224 Pine St., Niagara Falls, N. Y.
Fortsch, Arthur Ray	Iowa 1917	1123 Superior Ave., Whiting, Ind.
Foster, Angier Hobbs	Calif.	Langley Field, Hampton, Va.
Foster, Goodwin LeBaron	Washington 1914	
Foster, Laurence Fleming	Calif. 1921	398 Sixtieth St., Oakland, Calif.
Foster, Ora Frendh	Ill. 1914	Pavilion, Mich.
Foster, Walter L.	Columbia 1923	University Club, Bridgeport, Conn.
Fotte, Francis S., Jr.	Columbia 1908	
Foulk, Howard Vanton	Mich. 1913	
Fowler, Kenneth	Chicago 1921	5618 Kimbark Ave., Chicago, Ill.
Fox, Benjamin	Penn. 1911	U. S. Navy Yard, Brooklyn, N. Y.
Foxwell, George Lester	Nebr. 1925	1335 "C" St., Lincoln, Nebr.
Fraleigh, Percy Austin	Cornell 1917	118 Cascadilla Ave., Ithaca, N. Y.
France, Floyd Hill	Worcester 1924	Box 531, Mo. Col. of Mines, Rolla, Mo.
Francis, Mrs. Hugh (Dr. Helen Lucile Williamson)	Stanford 1918	Mills College, Oakland, Oakland, Cal.
Francis, Paul Hart	Brown 1912	1526 Broad St., Providence, R. I.

Name	*Chapter*	*Last Known Address*
Franck, Herman, Jr.	Union 1913	Y.M.C.A., Paterson, N. J.
Frane, Ivan Alan	Ill. 1923	State Highway Com., Depue, Ill.
Franke, Elizabeth C.	Columbia 1917	
Frankel, Samuel Henry	Union 1915	335 Duane Ave., Schenectady, N. Y.
Franzen, Raymond Hugh	Calif. 1924	
Frary, Gladys May	Cornell 1915	2166 Park Ave., Sandiego, Calif.
Fraser, David Kennedy	Cornell 1915	83 Great King St., Edinburgh, Scotland
Fraser, Donald	Ore. 1926	Occidental College, Eagle Rock, Los Angeles, Calif.
Frear, Jenness B.	Minn. 1910	Am. Radiator Co., Rano St., Buffalo, N. Y.
Frederighi, Henry	Rutgers 1923	Harvard University, Cambridge, Mass.
Freeman, Frances Rowland	Ohio 1910	Dept. Home Economics, Univ. of Maine, Orono, Maine
Freeman, Harriette	Ill. 1923	Univ. of Illinois, Dept. of Botany, Urbana, Ill.
Freeman, Herbert Augustine	Brown 1904	Crocker Wheeler Co., Ampere, N. J.
Freezee, W. D.	Purdue 1921	2582 Springle Ave., Detroit, Mich.
Freiberg, George William	Wash. 1915	5145 Kensington Ave., St. Louis, Mo.
Frese, Frances G.	Chicago 1921	814 S. Oakley Blvd., Chicago, Ill.
Frese, Frank Graham	Chicago 1925	Kent Lab., Univ. of Chicago, Chicago, Ill.
Fretz, Mary E.	Nwstn. 1922	Mt. Wilson Observatory, Pasadena, Cal.
Freudenberg, Werner	Calif. 1931	2705 Virginia St., Berkeley, Calif.
Frew, Harold L.	Case 1922	1606 Crawford Rd., Cleveland, Ohio
Frey, J. W.	Wis. 1925	Geology Dept., Science Hall, Univ. of Wisconsin, Madison, Wis.
Fricke, Russell Edward	Wash. 1925	
Friedemann, Theodore E.	Wash.	Dept. of Biological Chemistry, Washington Univ., St. Louis, Mo.
Friedemann, Theodore H.	Wash.	Washington Univ. Medical School, 602 S. Euclid Ave., St. Louis, Mo.
Friedrich, Martin E. P.	Ill. 1929	206 Chemistry Bldg., Univ. of Illinois, Urbana, Ill.
Frisch, Ragnar	Yale 1931	Economics Dept., Yale University, New Haven, Conn.
Fritzschi, Kurt W.	Wis. 1929	921 New Birks Bldg., Montreal, P. Q., Canada
Frizell, Arthur	Kansas 1910	
Froemke, John A.	N. D. 1925	University Station, Grand Forks, N. D.
Frudden, Conrad E.	Columbia 1910	

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